Appendix D
Automatic Data Acquisition Systems

D-1. Introduction

Computer-based automated data acquisition systems have become a valuable means of collecting geotechnical instrumentation data. Developments in the field of electronics have made it possible to install and operate remote data acquisition systems that provide accurate, reliable, and effective real time data collection. With the increased emphasis on dam safety and the continued decrease in available manpower, the advantages of providing automatic systems are numerous. Many tasks that are traditionally done by instrumentation personnel are better accomplished by machines since the machine will take measurements in the same manner at each reading. Human error can cause minor variations in reading and interpreting data. Automation also permits a greater volume of data to be collected in a given period of time, and data can be collected during significant events at remote sites when personnel may not be available or able to access the site. The automated system must not relieve or replace the normal visual inspection schedule of project features. The cost of instrumentation and computers to monitor instrumentation has decreased so that in many cases it is now more economical, in terms of overall cost and more consistent data, to automate the reading of instruments than to continue reading them manually. Since automation is a new technology, efforts to standardize sensors, communications, and software should be made in each FOA.[1] A database for automated geotechnical and some structural instrumentation at Federal and non-Federal projects is maintained under the Corps of Engineers Computer Applications in Geotechnical Engineering (CAGE) Program.[2]

D-2. Requirements of an Automatic Data Acquisition System

Considerable thought must be given in the design of a system for each individual project to ensure that the system produces the desired information in a meaningful, dependable, and reliable manner. While much flexibility in system design is available, each system should include the following basic requirements.

[1] Additional information is given in United States Committee on Large Dams (1993).
[2] Additional information is given in ETL 1110-2-316.

a. The ability to manually read each instrument must be maintained.

b. Each instrument should have the capability to be read automatically at the site.

c. The system should utilize microcomputers to collect and process data which can be accessed at any time at the project, at the District office, or at other designated locations. The system should also be capable of performing a quality control check of instrument readings, respond to preset threshold levels, and interface with existing District hardware and software applications.

d. A backup communication link to the District office should be provided for data transmission.

e. Considerations should also be given to a backup power supply, maintenance, vandalism protection, system diagnosis, and software versatility. Because of the amount of electrical circuits, lightning protection is essential.

D-3. System Configuration

A rendering of a typical project automation plan is shown in Figure D-1. A photo showing a remote monitor unit is in Figure D-2. Components of such a system would typically consist of the following:

a. Sensors. Sensors should be selected based on desired function, data required, and economics. Types of geotechnical and related instrumentation which can be automated are shown in Table D-1. Some considerations in the selection of sensors are provided below.

(1) Accuracy. Only the required level of accuracy should be specified since special sensors, extra documentation, and more expensive transmission lines required for the higher accuracy can significantly add to project cost.

(2) Range. A flexible range and an over-range which prevents sensor damage should be chosen.

(3) Temperature compensation. Temperature compensation should be eliminated unless required.

(4) Material. Sensor composition must be compatible with the media in which it is located.

(5) Shock, vibration, acoustic bombardment. Remotely locating the sensor can reduce shock which may

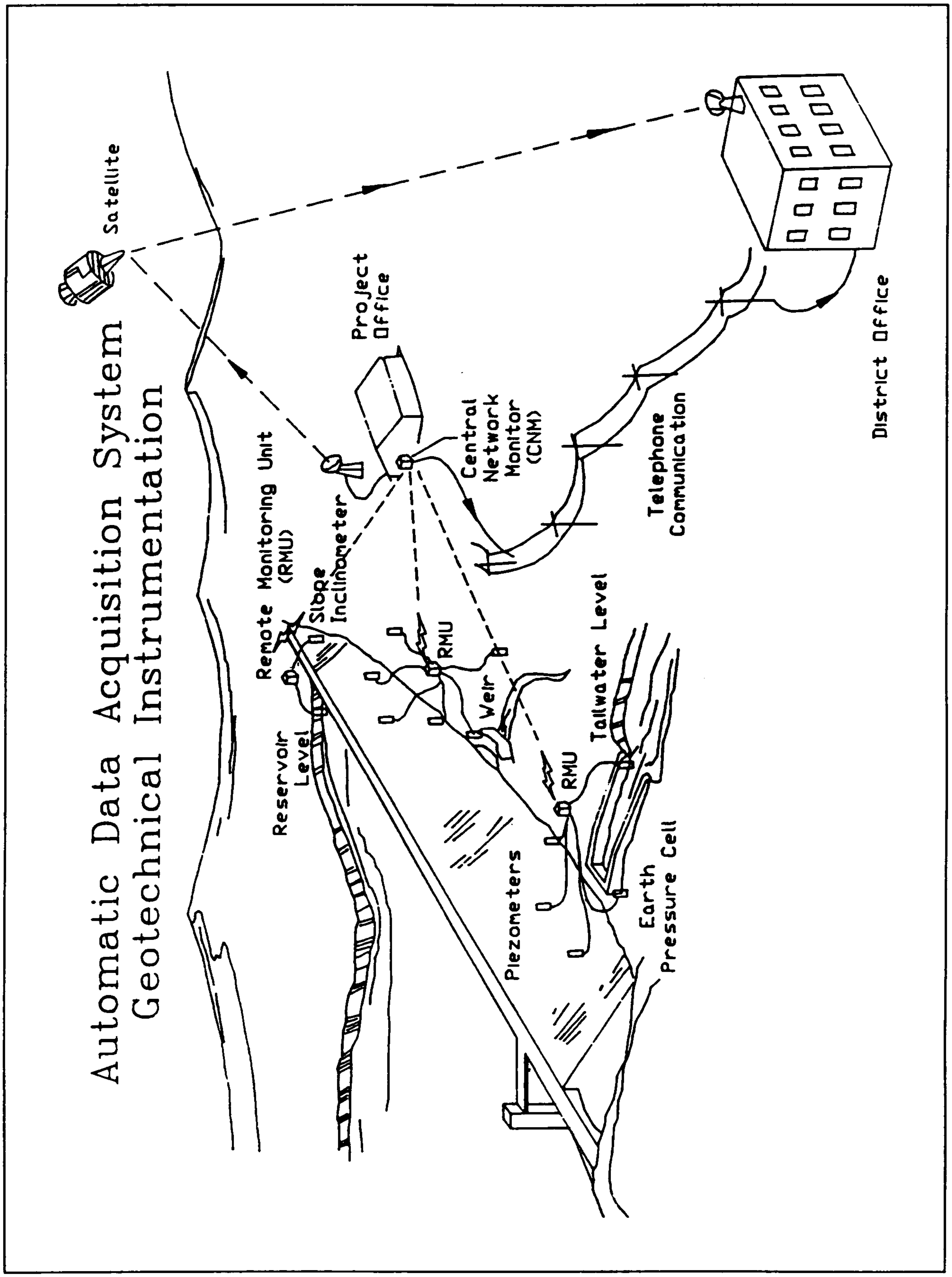

Figure D-1. Typical project automation plan

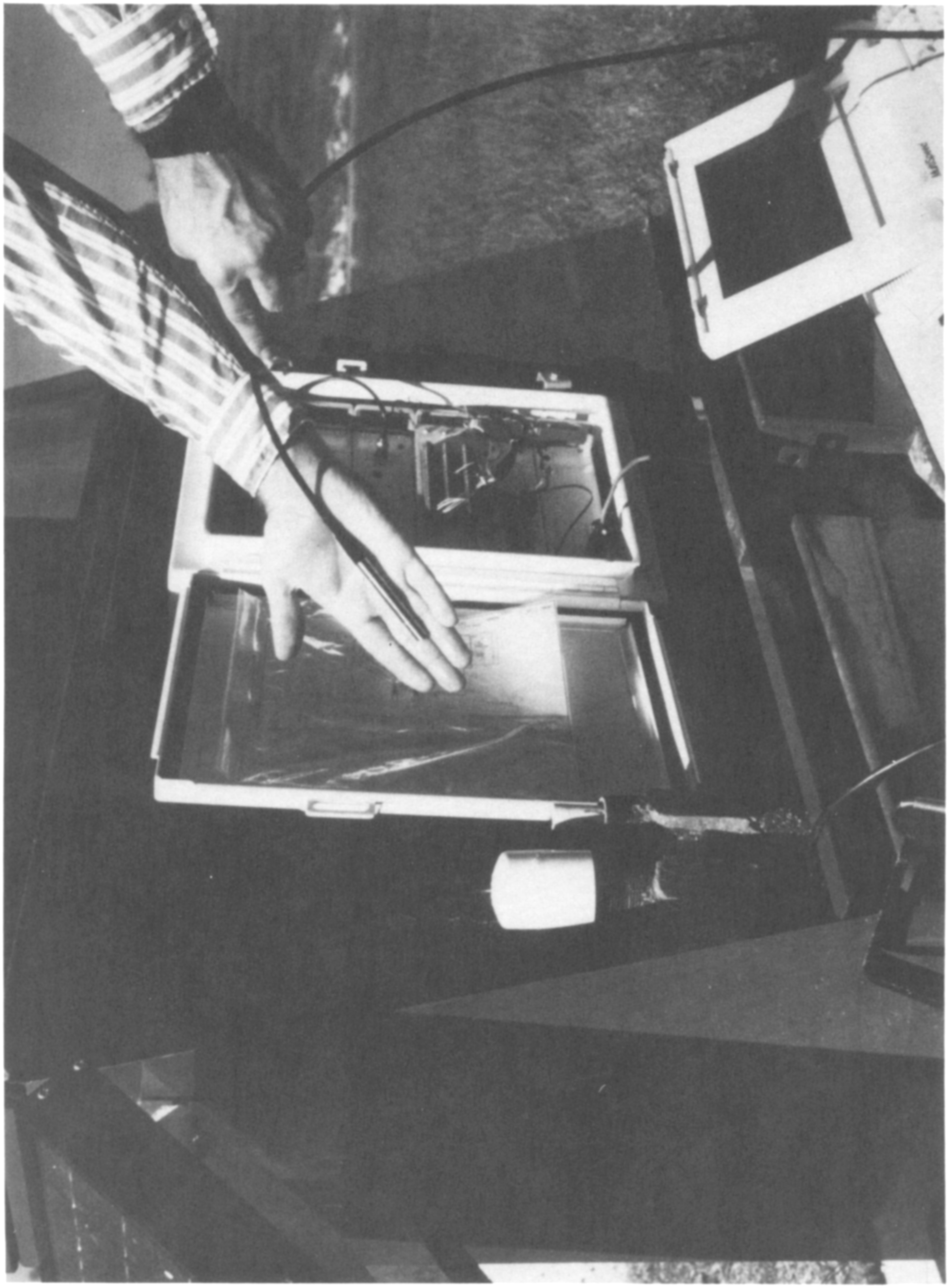

Figure D-2. Remote monitor unit in protective structure showing solar panel, pressure transducer, and portable computer

Table D-1
List of Dam Safety Instruments and Measurement Devices

Instrument or Measurement Device	Can Be Automated	Not Easily Automated
Piezometers:		
Standpipe	X	
Electrical	X	
Vibrating wire	X	
Pneumatic	X	
Hydraulic twin tube (USBR)	X	
Uplift (standpipe with gage)	X	
Inclinometers		X (1)
Borehole extensometers	X	
Plumblines	X	
Tiltmeters	X	
Temperature (concrete or fluid)	X	
Joint and deformation meters	X	
Stress and strain (strain gages)	X	
Weirs	X	
Staff gages	X	
Surface monuments		X
Settlement plates		X (2)
Soil pressure meter	X	
Channel scour survey data		X

NOTES: (1) Can be automated using a series of sensors.
(2) Certain methods of settlement sensing exist that can be automated.

permit selection of less expensive sensors, simpler mountings, and less expensive cable.

(6) Electrical characteristics. Sensitivity, impedance, and excitation should be selected to match the needs of the system.

b. Project computers. Computers at the site must be capable of monitoring geotechnical parameters, processing all data into meaningful terms, and communicating data to the District office. While commercially available systems have various configurations, each system basically consists of remote monitoring units located around a project site and a central network monitor located in the project office. Individual sensors are hard wired to the remote monitor units, which are capable of obtaining measurements from a number of sensors. Remote monitor units communicate with the central network monitor either by hard wire or by ultra-high-frequency radio link. The units are networked together so that they can automatically take measurements in a programmed sequence and store the data until they are interrogated from either the project office or the District office. The project microprocessors must also respond to measurement and data transfer commands from the project or District office at any time. General requirements for the remote monitor units and central network monitor are as follows:

(1) Full user programmability of all measurement and control functions.

(2) Operate stand-alone with a portable computer, independent of being connected to a hard wire or radio-based network.

(3) Store or buffer at least 16KB of data, with options to accept additional memory.

(4) Perform both linear and nonlinear engineering unit conversions on measured data.

(5) Perform alarm limits checking (both on a max/min and rate of change basis) in engineering units on measured data values.

(6) Capability of programming measurement cycles and frequency on an individual channel basis for all instrument channels.

c. Cabling. Individual sensors must be hard wired to the remote monitor unit. All cables should be placed in trenches to a sufficient depth for satisfactory and safe operation. In critical areas such as beneath roadways or slope protection, the cables should be placed in protective polyvinyl chloride conduits.

d. Power source. The monitoring units should have low power design such that solar panel capacity will be sufficient to keep the batteries in the units adequately charged. The units should be equipped with a nonswitch over (on line) uninterruptible power supply with a sealed internal battery. The power unit should provide power to all remote units including sensor inputs and communications devices.

e. District microcomputer. The central network monitor at the project office must be accessible by a microcomputer located in the District office. Basic communication between the project and the District is usually through telephone line modems. Backup communications such as by satellite link should be provided for emergency situations. Instrumentation data stored at the site must be accessible by the District computer at any time, and the system at the project site must also be capable of being queried for readings from the District at any time. Data should be presented in such a manner that it can be easily and rapidly evaluated and recorded for presentation in periodic inspection reports.

D-4. Retrofitting

Instrumentation automation retrofitting represents any effort to modify existing instruments so that they may be monitored completely under automated control, or such that the modification will aid instrumentation personnel in collecting the instrument data. Since the Corps has a large investment in structural safety-related instruments installed in dams throughout the country and since most of these instruments are still in working condition and still serving a useful purpose, keeping these instruments working rather than replacing them is in the best interest of the overall economy. Before considering a retrofitting operation, an analysis of whether the instrument retrofitting would be more cost-effective than purchasing new equipment should be made. Cost factors such as age of equipment to be retrofitted, cost of peripheral equipment which must be purchased to make the retrofit possible, as well as installation costs, must be weighed against the cost of new equipment and their installation costs before a wise decision regarding automation can be made. It is also important to consider accuracy and resolution of the older instruments, frequency of the data collection operations, information which is needed about the structure, accessibility of the site, and availability of personnel to make manual readings before making the decision on how to proceed.

D-5. Cost-Effectiveness and Priority of Automation

A review of all costs associated with automation of new dams and retrofitting existing dams by other agencies and initial test programs within the Corps of Engineers indicates that automation is cost-effective in making timely dam evaluations. The cost-effectiveness increases at projects or locations where access is limited due to terrain and/or weather, and at projects that experience considerable pool and/or tailwater fluctuations. Automation of existing projects within an FOA should be accomplished over a several year period and be based on priority of need. When determining priority of projects, consideration should be given to the consequences of failure, life of the structural features, nature of the structure with respect to the foundation and external loading, past performance, and remedial measures.